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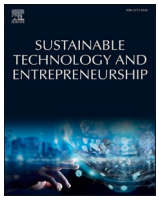

Full Length Article

# AI technology for developing Bitcoin investment strategies based on altcoin trends

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ABSTRACT

The objective of this study is to analyse the correlation between Bitcoin and altcoins in the post-covid world and take advantage of this possible relationship to design investment strategies on Bitcoin based on the evolution of altcoins using Artificial Intelligence (AI) models.

The sample of daily observations covers from January 2020 to February 2023, and the regressions performed between altcoins and Bitcoin are positive and 99 % significant, except for Dogecoin, which has a correlation with Bitcoin.

If we add a lag, the estimated parameters are still 95 % significant, except for Dogecoin, so we can assume that the return of altcoins anticipates the evolution of Bitcoin.

We train an artificial intelligence model in which the predictors are the observed daily return in altcoins and the target to predict is next day trend of Bitcoin (up or down). We use decision tree algorithms (J48), random forest and naive bayes, but in a retrospective cross-sectional validation with 10 sample partitions we obtain a poor predictive capacity of only a 51 % success rate in the best of cases.

Therefore, despite the evident correlation between predictors and the objective variable, we should not implement this investment strategy.

## Introduction

Blockchain technology has the potential to contribute to sustainability in various ways. By providing a secure and transparent way to track transactions and assets, blockchain can reduce fraud, corruption, and waste in various industries. The main concern about blockchain networks as a sustainable technology should be the energy consumption. Newer consensus mechanisms, such as Proof-of-Stake (PoS), are far less energy-intensive than PoW. Ethereum's transition from PoW to PoS with Ethereum 2.0 is an example of this shift towards more sustainable blockchain practices. Most of the altcoins uses PoS consensus mechanisms, not like Bitcoin that uses a PoW consensus. Understanding the correlation between altcoins and Bitcoin should provide a powerful tool for selecting different cryptocurrencies depending on their environmental impact, searching the most sustainable technology.

The cryptocurrency market, once the domain of a single digital pioneer, Bitcoin, has evolved into a diverse ecosystem teeming with alternative digital currencies, often referred to as "altcoins." These altcoins have garnered substantial attention and investment, each touting unique features, applications, and potential advantages over their predecessor. In the midst of this proliferation, some a crucial question looms: to what extent do altcoins correlate with Bitcoin and can their movements be predicted in tandem with the world's foremost cryptocurrency?

This paper embarks on an in-depth exploration of the complex interplay between Bitcoin and the ever-expanding universe of altcoins. It seeks to unveil the nature of their correlations, offering insights into whether altcoins move in harmony with Bitcoin or chart independent paths within the volatile cryptocurrency market. Furthermore, it delves into the predictability of altcoin performance concerning the leading digital currency.

The paper's journey commences by dissecting the foundational principles of Bitcoin, doing research on its historical performance, and scrutinizing its role as both a digital asset and a currency. It explores the factors that drive Bitcoin's market dynamics, such as adoption trends, regulatory developments, and macroeconomic conditions.

Subsequently, the spotlight shifts to the realm of altcoins, each possessing distinct attributes and utilities. We delve into the multitude of altcoin categories, including privacy-focused coins, utility tokens, and smart contract platforms. Through comprehensive data analysis, we

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seek to discern patterns in altcoin behavior and identify key drivers of their price movements. Fig. 1 shows the price evolution of the cryptocurrencies analyzed here.

One of the main focuses of this paper is the examination of correlations between Bitcoin and altcoins across different timeframes, in order to develop an AI prediction model between Bitcoin and altcoins. We analyze historical data to uncover the degree of correlation, exploring the factors that may influence synchronous or divergent movements. Additionally, we investigate the predictive potential of these correlations, shedding light on whether altcoin movements can be anticipated on the basis of Bitcoin's performance.

Beyond correlations, we delve into predictive models and methodologies employed in forecasting Bitcoin trends using the altcoin performance as predictor. We assess the validity and reliability of such models, taking into account variables such as trading volume, market sentiment, and technological developments.

In conclusion, this paper aims to contribute to a deeper understanding of the intricate relationship between altcoins and Bitcoin. By exploring the nuances of their correlations and the potential for predictability, we seek to empower investors, researchers, and cryptocurrency enthusiasts with valuable insights into navigating the dynamic and evolving landscape of digital currencies.

## Theoretical framework

The convergence of two transformative technologies—cryptocurrencies and artificial intelligence (AI)—has heralded a new era of innovation and disruption across multiple domains. On one hand, cryptocurrencies have challenged traditional financial systems, redefining the way we perceive and interact with money, assets, and transactions. On the other hand, AI, with its ability to process vast amounts of data, recognize patterns, and make autonomous decisions, is reshaping industries ranging from finance to healthcare.

This theoretical framework embarks on an exploratory journey through the intricate interaction between cryptocurrencies and AI. It seeks to illuminate the synergies, challenges, and opportunities that emerge when these two groundbreaking technologies intersect. By developing a structured framework, this research lays the groundwork for a comprehensive understanding of their dynamic relationship.

As we embark on this theoretical journey, we recognize the transformative power of both cryptocurrencies and artificial intelligence and their potential to reshape our economic, social, and technological landscapes. Through the lens of this theoretical framework, we seek to illuminate the path forward, where these technologies converge, innovate, and drive unprecedented change.

### *Bitcoin and altcoins*

Cryptocurrencies are digital or virtual currencies that use cryptography for security and operate independently of a central bank or government authority. They are, therefore, decentralized and typically based on blockchain technology, which is a distributed ledger that records all transactions across a network of computers (Böhme, Christin, Edelman & Moore, 2015).

Bitcoin (BTC) is a decentralized digital currency that was created in 2009 by an anonymous person or group of people using the pseudonym Satoshi Nakamoto (Yermack, 2015). It was the first cryptocurrency and remains the most well-known and widely used.

Bitcoin's History in Brief follows these steps (Antonopoulos, 2017):

1. Conceptualization (2008): Bitcoin's story began in August 2008 when a person or group using the pseudonym Satoshi Nakamoto published a whitepaper entitled "Bitcoin: A Peer-to-Peer Electronic Cash System." This whitepaper outlined the concept of a decentralized digital currency.
2. Genesis Block (2009): On January 3, 2009, Nakamoto mined the first Bitcoin block, known as the "genesis block" or "block 0," marking the launch of the Bitcoin network. The embedded message in this block read, "The Times 03/Jan/2009 Chancellor on brink of second bailout for banks," emphasizing Bitcoin's aim to provide an alternative to the traditional financial system (Popper, 2015).
3. Early Development (2009–2010): Bitcoin's early days saw its adoption by a small community of enthusiasts and developers. The first recorded Bitcoin transaction occurred in May 2010 when a programmer named Laszlo Hanyecz purchased two pizzas for 10,000 Bitcoins, establishing the first real-world exchange rate.
4. Mt. Gox Era (2010–2013): The now-defunct exchange, Mt. Gox, played a central role in Bitcoin's early history, becoming the

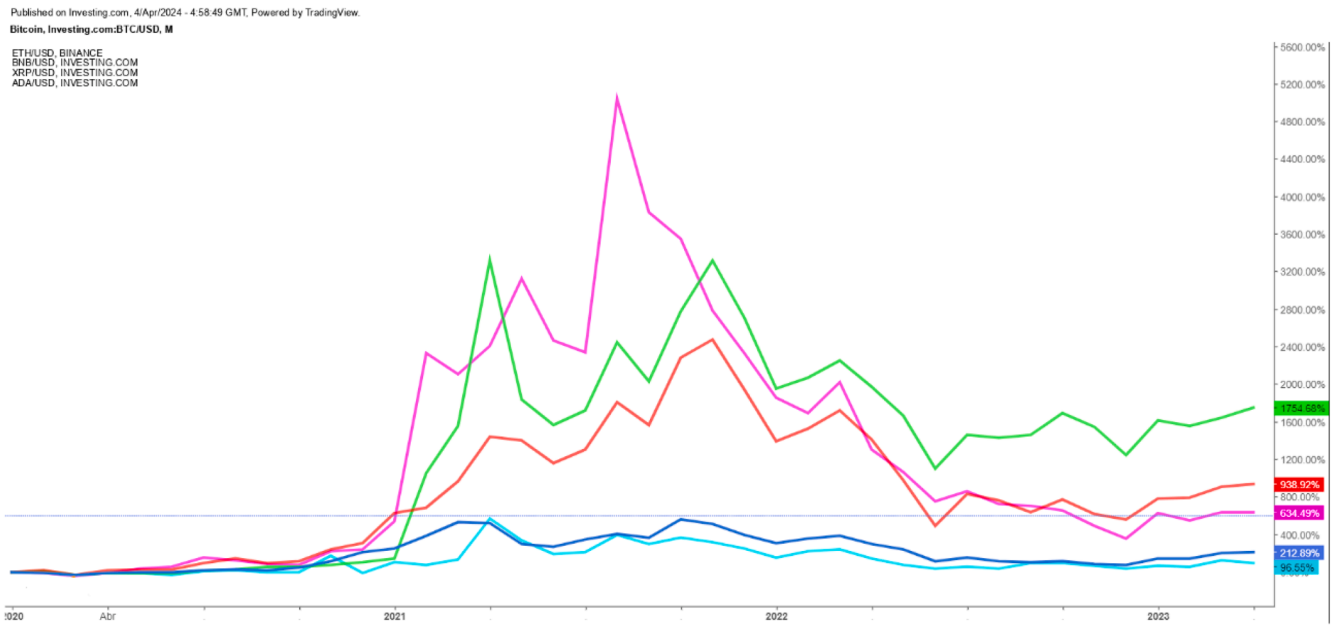


**Fig. 1.** Bitcoin and selected Altcoins price evolution.

primary platform for trading Bitcoins. During this period, Bitcoin's price experienced significant volatility.
5. Rapid Growth and Adoption (2013–2017): Bitcoin's price surged in 2013, reaching over $1000 per BTC, attracting mainstream attention. Over the next few years, Bitcoin saw increased adoption by businesses, investment firms, and individual users.
6. Scaling Debate (2017): A debate over Bitcoin's scalability led to a contentious fork in August 2017, resulting in the creation of Bitcoin Cash (BCH). This debate centered on how to increase the network's transaction capacity.
7. Institutional Interest (2017-Present): Bitcoin's legitimacy as an asset class grew, with large institutional investors and financial firms entering the market. The launch of Bitcoin futures on major exchanges further legitimized its status.
8. All-Time Highs and Volatility (2020–2021): Bitcoin's price surged to new all-time highs in late 2020 and early 2021, reaching over $60,000 per BTC. However, it also experienced periods of significant price volatility.
9. Regulatory Developments: Governments and regulatory bodies have been actively exploring and establishing frameworks for cryptocurrency regulation to address issues like money laundering, taxation, and consumer protection.
10. Ongoing Evolution: Bitcoin continues to evolve, with discussions about its role as a digital store of value, potential scaling solutions, and its place in the global financial system.

Bitcoin's journey from its creation to its current status as a recognized asset class has been marked by innovation, challenges, and transformative effects on the financial industry. Its future remains the subject of ongoing debate and development as it continues to shape the landscape of digital finance (Lewis, 2018).

Bitcoin operates on a peer-to-peer network, meaning that transactions can be made directly between users without the need for intermediaries like banks or payment processors. It utilizes blockchain technology, a distributed ledger that records all transactions in a transparent and immutable manner (Baur & McDermott, 2010).

One of the key features of Bitcoin is its limited supply. There will only ever be 21 million bitcoins in existence, as programmed in its protocol. This scarcity, combined with increasing demand, has contributed to Bitcoin's reputation as a store of value and a potential hedge against inflation (Franco, 2015).

Bitcoin transactions are secured through cryptographic algorithms (Franco, 2015) and are verified by network participants known as miners. Miners use powerful computers to solve complex mathematical problems, and in return for their computational efforts, they are rewarded with new bitcoins.

Eventually, Bitcoin has gained popularity as a decentralized currency, a speculative investment (Gandal, Hamrick, Moore & Oberman, 2018), and a means of transferring value globally. Nonetheless, it has experienced significant price volatility over the years, with periods of rapid growth followed by sharp corrections. Despite its volatility, Bitcoin has achieved widespread adoption and has inspired the development of thousands of other cryptocurrencies, collectively known as altcoins (Guesmi, Saadi, Abid & Ftiti, 2019).

Altcoins, short for "alternative coins," are cryptocurrencies other than Bitcoin. While Bitcoin was the first and most well-known cryptocurrency, the success and popularity of Bitcoin inspired the development of thousands of other cryptocurrencies. These alternative coins are collectively referred to as altcoins (Cagli, 2019).

Altcoins' History in Brief would be the following one (McDonald, 2023):

1. Emergence (2011–2013): Altcoins, or alternative cryptocurrencies, began to emerge as alternatives to Bitcoin, primarily from 2011 onwards. Namecoin, launched in April 2011, was one of the earliest altcoins and aimed to provide domain name registration services with enhanced privacy.
2. Litecoin and Scrypt-Based Coins (2011): Litecoin, created by Charlie Lee in October 2011, was a notable early altcoin. It introduced the Scrypt hashing algorithm, aiming to be "silver" to Bitcoin's "gold." Litecoin's success inspired the creation of other Scrypt-based coins.
3. Forking and Variations (2013–2014): Several altcoins emerged through forks (code modifications) of the Bitcoin protocol. Examples include Peercoin (2012) and Dogecoin (2013). These altcoins often introduced unique features like proof-of-stake (PoS) and changed block generation times.
4. Ethereum and Smart Contracts (2015): Ethereum, launched by Vitalik Buterin in 2015, introduced the concept of smart contracts. These self-executing contracts enabled developers to create decentralized applications (DApps) on the Ethereum blockchain, setting a new standard for altcoins.
5. ICO Boom (2017): The Initial Coin Offering (ICO) boom in 2017 saw the creation of numerous altcoins as fundraising mechanisms for blockchain projects. Many of these altcoins were built on the Ethereum platform.
6. Privacy Coins (2013-present): Privacy-focused altcoins like Monero (2014) and Zcash (2016) aimed to provide enhanced anonymity and transaction privacy compared to Bitcoin.
7. Stablecoins (2014-present): Stablecoins like Tether (USDT) and USDC emerged to provide cryptocurrency tokens pegged to real-world assets like the US dollar, aiming for price stability and utility in crypto transactions.
8. DeFi and Tokens (2018-present): The rise of decentralized finance (DeFi) led to the creation of numerous tokens on platforms like Ethereum. These tokens facilitated a wide range of financial services, including lending, borrowing, and decentralized exchanges.
9. Evolving Landscape (2020s): The altcoin landscape continues to evolve with new projects and technologies. NFTs (Non-Fungible Tokens) have gained prominence, and altcoins explore scalability solutions, interoperability, and sustainability.
10. Market Dynamics: Altcoins have experienced periods of rapid growth, followed by market corrections and volatility. Their fortunes often correlate with Bitcoin's performance, but they can also chart independent trajectories based on unique features and use cases.

The history of altcoins reflects the dynamic and innovative nature of the cryptocurrency space, with each altcoin aiming to address specific challenges or offer distinct advantages within the broader blockchain ecosystem (Baron, OMahony, Manheim, & Dion-Schwarz, 2015).

Altcoins can differ from Bitcoin in various aspects, such as their underlying technology, consensus mechanisms, features, and goals. Some altcoins aim to improve upon the limitations of Bitcoin, while others focus on specific use cases or industries (Chuen, Guo & Wang, 2017)

Despite the fact that Bitcoin and altcoins–which are alternative cryptocurrencies–share fundamental similarities as digital assets operating on blockchain technology, they are different in some key aspects. These are some of the main differences between Bitcoin and altcoins (McDonald, 2023):

- Genesis and Creator:

  ○ Bitcoin: Bitcoin was the first cryptocurrency, created by an anonymous entity or group known as Satoshi Nakamoto in 2008. It was introduced in 2009.
  ○ Altcoins: Altcoins are all cryptocurrencies other than Bitcoin. They were created after Bitcoin's launch and have various founders and development teams.

- Purpose and Use Cases:

  ○ Bitcoin: Bitcoin is often referred to as "digital gold" and primarily serves as a store of value and a medium of exchange. Its primary purpose is to function as a decentralized digital currency and an alternative to traditional fiat currencies.
  ○ Altcoins: Altcoins have a diverse range of purposes and use cases. They may intend to improve upon Bitcoin's technology, provide enhanced privacy, support smart contracts and decentralized applications (DApps), or serve niche markets such as gaming and content monetization.

- Technology and Algorithms:

  ○ Bitcoin: Bitcoin uses a proof-of-work (PoW) consensus algorithm based on the SHA-256 hashing function. This is often referred to as the "original" PoW algorithm.
  ○ Altcoins: Altcoins employ various consensus algorithms, including PoW, proof-of-stake (PoS), delegated PoS, and more. Altcoins often differentiate themselves from Bitcoin by using different hashing algorithms, consensus mechanisms, and technological features.

- Market Capitalization and Popularity:

  ○ Bitcoin: Bitcoin has the highest market capitalization and is the most widely recognized and adopted cryptocurrency. It dominates the cryptocurrency market in terms of value and liquidity.
  ○ Altcoins: Altcoins collectively make up a significant portion of the cryptocurrency market, with various coins having their own market niches and communities. However, none have reached the level of dominance that Bitcoin has achieved.

- Volatility and Price Movements:

  ○ Bitcoin: Bitcoin's price is known for its volatility, but it tends to be less volatile in comparison with many altcoins. It often sets the tone for overall market sentiment.
  ○ Altcoins: Altcoins can exhibit extreme price volatility, with rapid price fluctuations. Some altcoins may experience significant price gains or losses over short periods.

- Development and Innovation:

  ○ Bitcoin: Bitcoin's development is known for its cautious and conservative approach to changes and upgrades. Major upgrades require broad consensus among participants.
  ○ Altcoins: Altcoin development tends to be more experimental and agile, allowing for faster innovation and adaptation. This can lead to the rapid introduction of new features and technologies.

- Regulatory Considerations:

  ○ Bitcoin: Bitcoin is often more widely recognized by regulators and financial authorities, which can lead to specific regulatory frameworks being developed.
  ○ Altcoins: Altcoins may face varying degrees of regulatory scrutiny, with some governments and jurisdictions treating them differently from Bitcoin.

The cryptocurrency landscape is dynamic and new altcoins and changes in the existing ones continue to emerge. Each altcoin has its unique features and characteristics, so it is crucial to conduct thorough research and due diligence when considering investments or using specific cryptocurrencies.

*Cryptocurrencies, blockchain and sustainable technology*

Blockchain characteristics as a sustainable technology have been widely studied (Martínez, Carracedo, Comas y Siemens, 2022). Blockchain technology-based Cryptocurrencies are not considered inherently sustainable due to several factors. The first one is the energy consumption. Cryptocurrency mining, especially on networks like Bitcoin, requires a significant amount of energy. The process of validating transactions and solving complex computational algorithms consumes substantial amounts of energy, which can have a negative environmental impact if sourced from non-renewable sources. Consequently, the high energy consumption of cryptocurrency mining often leads to significant carbon emissions. This point is especially worrisome when the energy is obtained from non-renewable energy sources such as coal or natural gas, which contribute to climate change and other environmental issues (Miraz, Excell & Rafiq, 2021).

Hence, switching investment from Bitcoin to other altcoins that are more energy-efficient may indeed be a strategy worth considering, especially in the case of investors concerned about the environmental impact of cryptocurrency mining. They should take into account that altcoins that use consensus mechanisms other than Proof of Work (PoW), which is the energy-intensive mining method used by Bitcoin, may have a lower environmental impact. For example, altcoins that utilize Proof of Stake (PoS), require significantly less energy for transaction validation. Accordingly, diversifying cryptocurrency portfolio beyond Bitcoin can help spread risk and, potentially, capture opportunities in emerging altcoins with innovative technologies. By investing in a variety of altcoins, including those with more eco-friendly mining methods, investors can mitigate the impact of any single cryptocurrency's environmental concerns.

Nonetheless, before reallocating investments, it is crucial to conduct due diligence and meticulous analysis on alternative altcoins. Some factors such as the underlying technology, team expertise, market demand, and sustainability initiatives should be analyzed. It is worth considering projects that prioritize environmental sustainability and have a strong value proposition beyond just energy efficiency. While energy efficiency is an important consideration, it is also essential to assess the long-term viability and potential growth prospects of alternative altcoins. Finally, factors such as adoption rates, utility, scalability, and community support to determine their investment potential need to be evaluated.

To sum up, we can say that Bitcoin, which uses the Proof-of-Work (PoW) consensus mechanism, is generally less sustainable than altcoins that use Proof-of-Stake (PoS) due to the significant differences in energy consumption between the two methods.

*Artificial intelligence*

Artificial intelligence (AI) refers to the simulation of human intelligence in machines that are programmed to think and learn like humans (Dahlbom, 1993). It is a multidisciplinary field of study and research that focuses on creating intelligent systems capable of performing tasks that typically require human intelligence (Russell & Norvig, 2022).

AI systems are designed to perceive their environment, understand, and interpret data, reason and make decisions, and take appropriate actions (Boden, 2018). These systems often leverage techniques such as machine learning, natural language processing, computer vision, and robotics to mimic cognitive functions.

The history of Artificial Intelligence in brief is as follows:

1. Pre-20th Century Speculation (Antiquity-20th Century): The concept of creating machines that mimic human intelligence dates to ancient times, with myths of automatons and mechanical beings. In the 20th century, early AI pioneers like Alan Turing laid the theoretical foundations for AI with his concept of a universal machine (Luger, 2009).

2. Birth of AI as a Field (1950s-1956): The term "artificial intelligence" was coined in the 1950s, marking the official beginning of AI as a field of research. Early AI projects included the Logic Theorist and the General Problem Solver (GPS).
3. Dartmouth Conference (1956): The Dartmouth Conference in 1956 is considered the birth of AI as an academic discipline. John McCarthy, Marvin Minsky, Nathaniel Rochester, and Claude Shannon organized the event, where the attendees discussed the potential of machines to simulate human intelligence.
4. AI Winter (1970s-1980s): During this period, progress in AI research slowed, leading to what became known as "AI winters." Funding and interest in AI dwindled due to overhyped expectations and challenges in achieving human-like AI.
5. Expert Systems and Narrow AI (1980s-1990s): AI research shifted focus to "narrow" or specialized AI, leading to the development of expert systems. These systems, designed for specific tasks, found applications in areas like medical diagnosis and finance.
6. Machine Learning Resurgence (1990s-Present): Advances in machine learning, particularly neural networks and deep learning, rejuvenated AI research. Improved hardware, large datasets, and algorithmic innovations enabled significant progress in natural language processing, computer vision, and more.
7. AI in the Modern Era (2000s-Present): AI technologies have become integral to daily life, with applications in virtual assistants (e.g., Siri, Alexa), recommendation systems (e.g., Netflix, Amazon), autonomous vehicles, robotics, and healthcare (Davenport, 2018).
8. AI Achievements: Recent achievements include AlphaGo's victory over a human Go champion, GPT-3's natural language processing capabilities, and advancements in self-driving cars and healthcare diagnostics.
9. Ethical and Societal Considerations: As AI has advanced, discussions on ethical and societal implications have grown. Topics include bias in AI algorithms, job displacement, privacy concerns, and regulation.
10. Future Directions: AI continues to evolve with research in quantum computing, explainable AI, and reinforcement learning, among others. The field is expected to play a pivotal role in solving complex global challenges.

AI's history has been marked by periods of excitement, stagnation, and resurgence. Today, it stands as a transformative force with profound implications for various industries and society (Russell & Norvig, 2022).

Machine learning is a subset of AI that involves training algorithms on large datasets to recognize patterns and make predictions or decisions without being explicitly programmed for each scenario. Deep learning, a subfield of machine learning, utilizes artificial neural networks with multiple layers to enable more complex and nuanced pattern recognition (Alpaydin, 2020).

Key characteristics of machine learning include:

1. Learning from Data: Machine learning algorithms learn patterns and relationships from data. The more data they have, the better they can learn and improve their performance.
2. Generalization: Machine learning models aim to generalize from the data they have been trained on to make predictions or decisions on new, unseen data. This ability to generalize is a fundamental aspect of machine learning.
3. Automated Improvement: Machine learning systems can automatically refine their performance over time as they receive more data or feedback. This process is known as training.
4. Diverse Applications: Machine learning has a wide range of applications, including image and speech recognition, natural language processing, recommendation systems, autonomous vehicles, and more.

Machine learning can be categorized into several types (Russell & Norvig, 2022):

1. Supervised Learning: In supervised learning, algorithms are trained on labelled data, where the input data is paired with the correct output. The algorithm learns to map inputs to outputs, making it suitable for tasks like classification and regression.
2. Unsupervised Learning: Unsupervised learning involves training algorithms on unlabeled data. The goal is to discover patterns, structures, or clusters within the data, making it useful for tasks like clustering and dimensionality reduction.
3. Reinforcement Learning: Reinforcement learning focuses on training agents to make sequences of decisions in an environment to maximize a reward. It is commonly used in robotics, game playing, and autonomous systems.
4. Semi-Supervised Learning: Semi-supervised learning combines elements of both supervised and unsupervised learning. Algorithms are trained on a combination of labelled and unlabeled data.
5. Deep Learning: Deep learning is a subfield of machine learning that uses artificial neural networks with many layers (deep neural networks). It has achieved remarkable success in tasks like image recognition, natural language processing, and speech recognition.

Machine learning is applied across various industries and domains, from healthcare and finance to e-commerce, entertainment, and education innovation (Gómez Martínez, Medrano García & Aznar Sánchez, 2023). It plays a crucial role in automating tasks, making predictions, improving decision-making, and advancing AI capabilities.

Artificial Intelligence (AI) and Machine Learning (ML) are related fields but have distinct differences (Alpaydin, 2020):

1. Scope and Definition:

- AI: AI is a broader concept that encompasses the development of machines or systems that can perform tasks that typically require human intelligence. AI aims to create systems capable of reasoning, problem-solving, understanding natural language, perceiving their environment, and learning from experience.
- ML: ML is a subset of AI focused on developing algorithms and models that allow computers to learn and make predictions or decisions based on data. ML is more specific, as it deals primarily with the development of techniques for learning patterns and making inferences from data.

2. Learning Approach:

- AI: AI systems can be rule-based and programmed explicitly to follow predefined rules and logic. They may also incorporate learning components, but AI can involve various methods beyond machine learning, such as expert systems and symbolic reasoning.
- ML: ML systems rely on data-driven learning. They learn patterns and relationships from data without being explicitly programmed. ML algorithms improve their performance as they receive more data and learn from experience.

3. Application Range:

- AI: AI has a broad range of applications beyond machine learning, including robotics, natural language processing, computer vision, expert systems, and more. AI encompasses both rule-based systems and data-driven approaches.
- ML: ML is specifically focused on data-driven tasks and is commonly used for tasks like image and speech recognition, recommendation systems, predictive modelling, and classification.

4. Learning Types:

- AI: AI systems can incorporate various learning approaches, including rule-based, symbolic reasoning, expert systems, reinforcement learning, and machine learning.
- ML: ML is primarily concerned with machine learning approaches, which include supervised learning, unsupervised learning, reinforcement learning, and deep learning.

5. Goal:

- AI: The goal of AI is to create machines or systems that can exhibit human-like intelligence across a wide range of tasks, including those that do not involve learning from data.
- ML: The goal of ML is to develop algorithms and models that can automatically improve their performance on specific tasks by means of data-driven learning.

In summary, AI is the overarching field that aims to create intelligent machines, while ML is a specific subset of AI focused on the development of algorithms and models that enable machines to learn from data. ML is a key component of AI, but AI encompasses a broader spectrum of techniques and applications beyond machine learning (Russell, Norvig, 2022).

AI has numerous applications across various domains, including:

- Healthcare: AI can assist in medical diagnosis, drug discovery, personalized treatment plans, and patient monitoring.
- Transportation: AI enables autonomous vehicles, traffic optimization, and logistics planning.
- Natural Language Processing: AI enables voice assistants, chatbots, and language translation.
- Robotics: AI is integral component in the development of autonomous robots used in manufacturing, healthcare, and exploration.
- Personalization: AI algorithms are used in recommendation systems, targeted advertising, and content curation.
- Cybersecurity: AI helps detect and respond to cyber threats, identify anomalies, and protect sensitive data.

Artificial Intelligence (AI) is applied to finance in various ways, revolutionizing the industry and improving decision-making, risk management, customer service, and operational efficiency. These are some key applications of AI in finance (Lo, 2018):

- Algorithmic Trading: AI algorithms analyze large datasets to identify trading patterns and execute high-frequency trades with minimal human intervention. Machine learning models can adapt to changing market conditions and optimize trading strategies (Zhang, Loh, Shuen & Wang, 2018).
- Risk Assessment and Management: AI models assess credit risk by analyzing borrowers' financial data and credit histories. AI-driven risk management tools can also evaluate market, operational, and compliance risks, helping financial institutions make informed decisions (Königstorfer, Thalmann, 2020).
- Fraud Detection: Machine learning algorithms can identify fraudulent transactions by analyzing historical data and detecting unusual patterns or anomalies. AI helps financial institutions to prevent fraud and reduce false positives, improving security and customer trust.
- Customer Service and Chatbots: AI-powered chatbots and virtual assistants provide real-time customer support, answer queries, and assist with account management. They offer personalized recommendations and enhance the customer experience.
- Personalized Financial Advice: AI-driven robo-advisors use customer financial data, goals, and risk tolerance to create personalized investment portfolios and provide investment advice. This lowers costs and makes financial advice more accessible.
- Credit Scoring: AI analyzes a wide range of data sources to create more accurate and predictive credit scores. This allows lenders to offer credit to a broader range of individuals and businesses, including those with limited credit histories.
- Algorithmic Lending: AI-driven platforms assess borrowers' creditworthiness and automate the lending process. These platforms use alternative data sources and machine learning models to make quick and data-driven lending decisions.
- Regulatory Compliance: AI helps financial institutions to comply with regulatory requirements by automating compliance checks, monitoring transactions for suspicious activity, and generating the reports required by regulators.
- Portfolio Management: AI tools assist portfolio managers in making investment decisions by analyzing market data, economic indicators, and news sentiment. They can optimize asset allocation and risk management strategies.
- Natural Language Processing (NLP): NLP techniques analyze news, social media, and financial reports to extract insights and sentiment about specific stocks, companies, or markets. This information can inform investment decisions.
- Quantitative Analysis: AI models support quantitative analysts (quants) in developing mathematical and statistical models for pricing financial instruments, risk management, and portfolio optimization.
- Insurance Underwriting: AI assesses insurance applicants' risk profiles by analyzing data from different sources, enabling insurers to price policies more accurately and efficiently.
- Trading Strategy Development: Machine learning models are used to develop and optimize trading strategies based on historical data and real-time market information.
- Predictive Analytics: AI predicts financial market trends, asset prices, and economic indicators, helping investors and financial institutions make informed decisions.

These applications of AI in finance (Li, Sigov, Ratkin, Ivanov & Li, 2023) enhance efficiency, reduce operational costs, improve risk management, and provide more personalized financial services. As technology continues to advance, AI is expected to play an increasingly crucial role in shaping the future of the financial industry.

The field of AI continues to evolve rapidly, with ongoing research and advancements contributing to its growth and potential impact on society. Ethical considerations, transparency, and responsible AI development are also crucial aspects to ensure the ethical and responsible use of AI technologies.

While artificial intelligence (AI) has shown promise in various fields, including finance, it is important to understand that predicting the evolution of financial markets with absolute accuracy is extremely challenging, if not impossible (Gómez-Martínez, Prado-Román & Plaza-Casado, 2019). Financial markets are influenced by numerous factors, including economic indicators, geopolitical events, investor sentiment, and unforeseen circumstances. The complexity and dynamic nature of these factors make it difficult to accurately predict market movements consistently.

Nonetheless, AI and machine learning techniques have been used in financial analysis to process vast amounts of data, identify patterns, and extract insights (Goodell, Kumar, Lin & Pattnaik, 2021). AI algorithms can analyze historical market data, news sentiment, social media trends, and other relevant information to identify potential correlations and patterns that humans may overlook. This analysis can be helpful in informing investment decisions and risk management strategies.

It is worth noting that AI-based predictions should be considered as tools for decision support rather than infallible predictors. Financial markets are influenced by human behavior, which can be irrational and subject to sudden shifts. Therefore, while AI can provide valuable insights and assist in decision-making, it is crucial to combine such insights with human judgment, expertise, and a comprehensive understanding of the broader economic and market landscape.

Hence, it is always advisable to approach financial investments with

caution, diversify portfolios, and consult with financial professionals or advisors who can provide personalized guidance taking into account individual circumstances and goals (Milana & Ashta, 2021).

## Sustainable technology, entrepreneurship, and artificial intelligence (AI)

The intersection of sustainable technology, entrepreneurship, and artificial intelligence (AI) presents a complex yet fertile ground for innovation, especially in the context of cryptocurrency trading. This paper explores how AI trading strategies for Bitcoin and altcoins align with sustainable technology and entrepreneurial goals (Gupta, Gaurav, Panigrahi & Arya, 2023). Analysis of artificial intelligence-based technologies and approaches on sustainable entrepreneurship. Technological Forecasting and Social Change, 186, 122,152.).

Sustainable technology refers to innovations and systems that minimize environmental impact, optimize resource efficiency, and contribute to long-term ecological balance. In financial markets, this can include green finance, sustainable investment strategies, and the development of energy-efficient systems for managing data and transactions (Goralski & Tan, 2020), particularly important in the energy-intensive world of cryptocurrency mining and trading.

Blockchain networks, such as Bitcoin, have been criticized for their high energy consumption. However, more sustainable alternatives like Proof of Stake (PoS) systems are emerging in altcoins, reducing the environmental footprint. Entrepreneurs in the FinTech space are increasingly focused on creating energy-efficient trading solutions that integrate sustainability (Kou, Olgu Akdeniz, Dinçer, et al., 2021).

Entrepreneurs in the cryptocurrency sector are leveraging AI to optimize trading strategies while incorporating sustainability goals, such as minimizing energy costs, promoting decentralized financial systems, and fostering economic resilience. Entrepreneurship in the cryptocurrency and AI sectors is driven by innovation, opportunity recognition, and scalability. The digital asset market, led by Bitcoin and various altcoins, provides fertile ground for FinTech entrepreneurship (Giuggioli & Pellegrini, 2023).

The rise of AI applications in cryptocurrency trading represents a significant entrepreneurial opportunity. Entrepreneurs leverage machine learning algorithms and predictive models to forecast market trends, identify trading patterns, and execute trades autonomously (Amirzadeh, Nazari & Thiruvady, 2022). These strategies present opportunities for economic growth while fostering financial inclusion through decentralized networks.

The entrepreneurial mindset in this domain extends beyond profitability to encompass ethical considerations like transparency, energy consumption, and risk management. Entrepreneurs are developing AI models that prioritize sustainable finance, incorporating variables like environmental impact and long-term value rather than short-term profit maximization.

AI has become an essential tool for predicting market behavior and executing trades in real-time, particularly in volatile markets like Bitcoin and altcoins. AI-driven trading strategies are founded on machine learning, deep learning, and reinforcement learning. AI models trained on historical cryptocurrency data can identify patterns and predict price movements. Techniques such as linear regression, time series analysis, and neural networks are used to forecast fluctuations in Bitcoin and altcoin prices (Babaei, Giudici & Raffinetti, 2022). The predictability of these models, however, depends largely on the quality of the data and the complexity of the model, which may be influenced by external factors like market sentiment and regulations.

The training of AI models for cryptocurrency trading also involves considerations of sustainability. Computational efficiency, data quality, and energy consumption are critical. Sustainable AI strategies emphasize the use of efficient algorithms and cloud computing powered by renewable energy sources (Khalid, 2024). The process of model training, particularly with energy-intensive techniques like deep learning, must consider environmental impacts to align with sustainability goals.

AI trading strategies offer a way to enhance the sustainability of cryptocurrency markets by improving market efficiency and reducing the environmental footprint associated with cryptocurrency mining and trading (Mustafa, Lodh, Nandy & Kumar 2022). Entrepreneurs who leverage AI in trading can achieve both financial and sustainable goals by:

- Optimizing trading algorithms that reduce energy consumption and maximize long-term financial sustainability.
- Utilizing predictive AI models that align with sustainability metrics, such as minimizing resource use or integrating environmental, social, and governance (ESG) factors into decision-making.
- Incorporating Google Trends and other indicators to gauge public sentiment, although their relevance is often secondary to geographic and market-type variables.

AI not only plays a role in predicting and executing trades in Bitcoin and altcoin markets but also serves as a tool for promoting sustainable financial practices. This interdisciplinary approach highlights the need for AI strategies that balance profitability, energy efficiency, and long-term sustainability in the dynamic world of cryptocurrency trading. Future research should further explore the relationship between cryptocurrency legitimacy (Plaza-Casado et al., 2024), sustainability metrics, and their influence on price dynamics to inform more ethical and efficient investment strategies (Del-Castillo-Feito et al., 2022).

## Hypothesis

Therefore, the hypothesis to validate in this study is the following one:

$H_0$: Artificial intelligence is a valid tool to predict the evolution of Bitcoin.

## Methodology

The methodology for this analysis follows the following stages:

Stage 1

We analyze the correlation between Bitcoin and the most relevant altcoins due to their market capitalization using linear regression models (Bouri, Vo & Saeed, 2021)), in which the daily return of Bitcoin is the dependent variable, while the explanatory variable is the daily return of the altcoin (Corbet, Meegan, Larkin, Lucey & Yarovaya, 2018). The altcoins selected for the study are Ethereum (ETH), Binance (BNB), Ripple (XRP), Cardano (ADA) Matic (MATIC) and Dogecoin (DOGE).

The models to be estimated at this stage of the study are the following ones:

| | |
|---|---|
| • $Var\_BTCt = a + b\ Var\_ETHt + ut$ | Model 1 |
| • $Var\_BTCt = a + b\ Var\_BNBt + ut$ | Model 2 |
| • $Var\_BTCt = a + b\ Var\_XRPt + ut$ | Model 3 |
| • $Var\_BTCt = a + b\ Var\_ADA\ t + ut$ | Model 4 |
| • $Var\_BTCt = a + b\ Var\_MATICt + ut$ | Model 5 |
| • $Var\_BTCt = a + b\ Var\_DOGEt + ut$ | Model 6 |

Where:

| | |
|---|---|
| • $Var\_BTC_t$ | is the daily return of Bitcoin during the season "t" |
| • $Var\_ETH_t$ | is the daily return of Ethereum during the season "t" |
| • $Var\_BNB_t$ | is the daily return of Binance Coin during the season "t" |
| • $Var\_XRP_t$ | is the daily return of Ripple during the season "t" |
| • $Var\_ADA_t$ | is the daily return of Cardano during the season "t" |
| • $Var\_MATIC_t$ | is the daily return of Matic during the season "t" |
| • $Var\_DOGE_t$ | is the daily return of Dogecoin during the season "t" |

The altcoins selected for the study are large caps and have captured the attention of the public in recent years. The criterion followed for the selection of cryptocurrencies participating in this study was based on

two conditions: at the time of the study, not being a cryptocurrency with an exchange rate linked to any fiat currency (primarily the dollar) and being in the top 10 cryptocurrencies by market capitalization.

***Stage 2***

If a significative correlation is observed in the regressions carried out, we will add a lag in the explanatory variable to identify its predictive capacity. The models have the same formulation, but adding a lag causes us to shift from analyzing predictive capacity to analyzing predictive capability.

The models to be estimated at this stage of the study are the following:

| | |
|---|---|
| • $Var\_BTC_t = a + b\ Var\_ETH_{t-1} + u_t$ | Model 7 |
| • $Var\_BTC_t = a + b\ Var\_BNB_{t-1} + u_t$ | Model 8 |
| • $Var\_BTC_t = a + b\ Var\_XRP_{t-1} + u_t$ | Model 8 |
| • $Var\_BTC_t = a + b\ Var\_ADA_{t-1} + u_t$ | Model 10 |
| • $Var\_BTC_t = a + b\ Var\_MATIC_{t-1} + u_t$ | Model 11 |
| • $Var\_BTC_t = a + b\ Var\_DOGE_{t-1} + u_t$ | Model 12 |

Where:

| | |
|---|---|
| • $Var\_BTC_t$ | is the daily return of Bitcoin during the season "t" |
| • $Var\_ETH_{t-1}$ | is the daily return of Ethereum during the previous season "t" |
| • $Var\_BNB_{t-1}$ | is the daily return of Binance Coin during the previous season "t" |
| • $Var\_XRP_{t-1}$ | is the daily return of Ripple during the previous season "t" |
| • $Var\_ADA_{t-1}$ | is the daily return of Cardano during the previous season "t" |
| • $Var\_MATIC_{t-1}$ | is the daily return of Matic during the previous season "t" |
| • $Var\_DOGE_{t-1}$ | is the daily return of Dogecoin during the previous season "t" |

Stage 3

If the delays are significant, artificial intelligence would be used to define investment strategies on Bitcoin based on the profitability observed the previous day in altcoins.

Taking into account that the objective variable of this AI model is dichotomous (up/down), using a coin instead of an AI model would give us a 50 % success rate. Therefore, to validate this hypothesis we will ask the model a percentage or correctly classified instances greater than 60 % in a tenfold retrospective cross validation. If we assume equal mathematical expectation for an upward and downward trend, an AI model with an accuracy greater than 50 % should be profitable. However, since the equality in mathematical expectations may not hold true, we add an additional 10 % margin to the model's accuracy to gain confidence in its profitability.

The machine learning techniques used in this analysis fall within the supervised learning models. The estimations of the models by linear regression will be made by means of the GRETL statistical software, while for the training and validation of the IA models we will use WEKA.

## Results

The results obtained for each stage of the analysis are:

***Stage 1***

Table 1 shows the correlation coefficients that represent the strength and direction of the linear relationship between Bitcoin (BTC) and selected altcoins. The meaning of each column is explained below:

• Coefficient: This column shows the correlation coefficient (r) between Bitcoin and each altcoin. The correlation coefficient should be interpreted as follows:

- ○ 1 indicates a perfect positive correlation (as Bitcoin's value increases, the altcoin's value also increases proportionally).
- ○ −1 indicates a perfect negative correlation (as Bitcoin's value increases, the altcoin's value decreases proportionally).
- ○ 0 indicates no correlation (there is no linear relationship between Bitcoin and the altcoin).

• Standard Dev.: This column displays the standard deviation of the correlation coefficient, which indicates the variability of the correlation estimate.

• t-stat: The t-statistic measures the significance of the correlation coefficient. Higher absolute values of the t-statistic indicate stronger evidence against the null hypothesis (that there is no correlation). In other words, the higher the t-statistic, the more significant the correlation.

• p-value: This column provides the p-value associated with the correlation coefficient. The p-value indicates the probability of observing the correlation coefficient (or one more extreme) under the assumption that there is no real correlation between Bitcoin and the altcoin. A lower p-value (typically $< 0.05$) suggests that the correlation is statistically significant and not due to random chance.

The sample of daily observations covers from January 2020 to February 2023, and the regressions performed between altcoins and Bitcoin are positive and 99 % significant, except for Dogecoin, which has a correlation with Bitcoin, as Table 1 shows.

If we use the $R^2$ parameter to evaluate the reliability of the estimated coefficient, we find that in all cases it exceeds 60 %, apart from Dogecoin again (Fig. 2).

Stage 2

If we add a lag (Table 2), the estimated parameters are still 95 % significant, except for Dogecoin, so we can assume that the return of altcoins anticipates the evolution of Bitcoin.

However, the reliability of the estimated coefficient is very low, being just over 1 % in the best results as shown in Fig. 3.

Stage 3

We train an artificial intelligence model in which the predictors are the observed daily return in altcoins and the target to predict is next day trend of Bitcoin (up or down). We use decision tree algorithms (J48), random forest and naive bayes Table 2.

The confusion matrix obtained for the retrospective cross validation are shown in Table 3.

In a retrospective cross-sectional validation with 10 sample partitions, we obtain a poor predictive capacity of only a 51 % success rate in the best of cases.

Therefore, in this case, despite the evident correlation between predictors and the objective variable, we should not implement this investment strategy.

**Table 1**
Linear correlation between Bitcoin and selected Altcoins.

| | Coefficient | Standard Dev. | t-stat | p-value | | | |
|---|---|---|---|---|---|---|---|
| Var_ETH | 0.622894 | 0.0125157 | 49.77 | 6.62e-289 | *** | Model | 1 |
| Var_BNB | 0.459122 | 0.0146031 | 31.44 | 5.00e-157 | *** | Model | 2 |
| Var_XRP | 0.357724 | 0.0144536 | 24.75 | 1.01e-108 | *** | Model | 3 |
| Var_ADA | 0.437263 | 0.0141429 | 30.92 | 3.43e-153 | *** | Model | 4 |
| Var_MATIC | 0.287672 | 0.0113247 | 25.40 | 2.56e-113 | *** | Model | 5 |
| Var_DOGE | 0.000448924 | 0.000614464 | 0.7306 | 0.4652 | Model | 6 | |

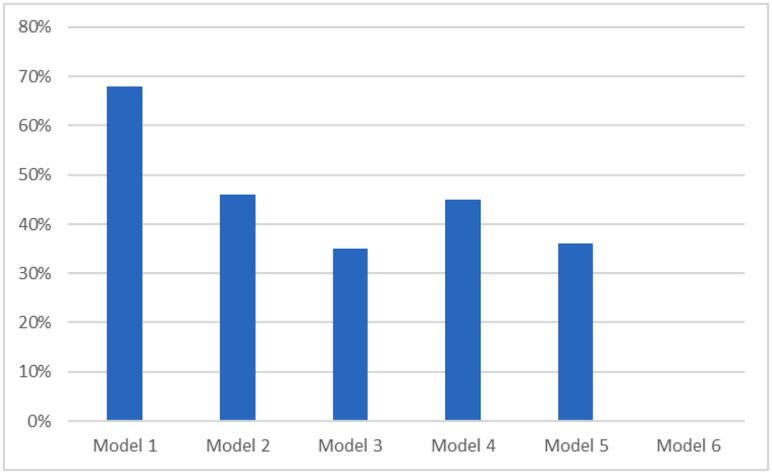


**Fig. 2.** R2 for linear correlation between Bitcoin and selected Altcoins.

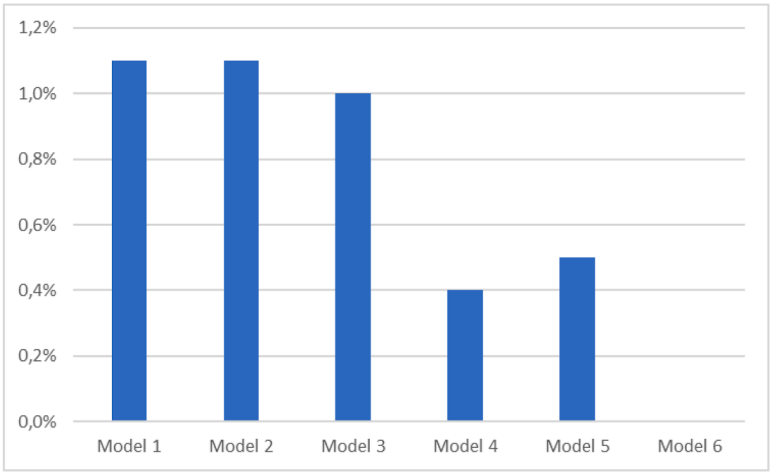


**Fig. 3.** $R^2$ for linear correlation between Bitcoin and a lag of selected altcoins.

**Table 2**
Linear correlation between Bitcoin and a lag of selected altcoins.

| | Coefficient | Standard Dev. | t-stat | p-value | | | |
|---|---|---|---|---|---|---|---|
| Var_ETH_1 | −0.0803656 | 0.0221234 | −3.633 | 0.0003 | *** | Model | 1 |
| Var_BNB_1 | −0.0723731 | 0.0198154 | −3.652 | 0.0003 | *** | Model | 2 |
| Var_XRP_1 | −0.0597062 | 0.0178198 | −3.351 | 0.0008 | *** | Model | 3 |
| Var_ADA_1 | −0.0419707 | 0.0191143 | −2.196 | 0.0283 | ** | Model | 4 |
| Var_MATIC_1 | −0.0338803 | 0.0141248 | −2.399 | 0.0166 | ** | Model | 5 |
| Var_DOGE_1 | −0.000194349 | 0.000614848 | −0.3161 | 0.7520 | Model | 6 | |

## Discussion

No one will dispute the fact that artificial intelligence is nowadays in the focus of public opinion. Whereas some extol its usefulness by identifying applications in any area of daily life, others warn of the dangers that it implies, in some cases extrapolating to a possible future reality argument from science fiction movies that we have already seen. In this context, it seems appropriate to carry out a rigorous analysis of what artificial intelligence can contribute in different fields of study. In this case, the study focuses on the world of cryptocurrencies, which is also in the focus of public opinion, arousing contradictory opinions in equal proportion.

This study has analyzed the correlation of different altcoins with respect to Bitcoin, the first and most important cryptocurrency by market capitalization and volume of transactions. A high correlation between these assets has been identified using linear regression models, even with lagged variables, which means some predictive capacity. This correlation allows investors to create diversified portfolios in altcoins more efficiently, and therefore more sustainably. Switching investment from Bitcoin to other altcoins depends on individual investment goals, risk tolerance, and ethical considerations. Nevertheless, investors can make informed decisions that align with their values and financial objectives by carefully weighing the environmental impact alongside other investment criteria.

Even though the identified predictive ability has been used to train artificial intelligence models, its success rate is very poor, so it is not worth even back-testing. If we assume equal mathematical expectation for an upward and downward trend, an AI model with an accuracy

**Table 3**
AI models confusion matrix.

```
Scheme:       weka.classifiers.trees.J48
=== Confusion Matrix ===
   a   b   <-- classified as
   0 562 |   a = DOWN
   0 588 |   b = UP

Correctly Classified Instances         588               51.1304 %
Incorrectly Classified Instances       562               48.8696 %

Scheme:       weka.classifiers.trees.RandomForest
 === Confusion Matrix ===
    a   b   <-- classified as
  240 322 |   a = DOWN
  252 336 |   b = UP

Correctly Classified Instances         576               50.087 %
Incorrectly Classified Instances       574               49.913 %

Scheme:       weka.classifiers.bayes.NaiveBayes
=== Confusion Matrix ===
   a   b   <-- classified as
 320 242 |   a = DOWN
 365 223 |   b = UP

Correctly Classified Instances         543               47.2174 %
Incorrectly Classified Instances       607               52.7826 %
```

greater than 50 % should be profitable. However, it is possible that this equality in mathematical expectations may not hold, so we add an additional margin of 10 % to the model's accuracy to gain confidence in its profitability.

A limitation of this study is the set of altcoins used. Extending this study to more altcoins and identifying patterns that allow us to know which ones will be correlated and which ones will not, seems to be an interesting line of future research. By expanding the scope to include a broader range of altcoins, researchers can gain a more comprehensive understanding of the correlations and patterns within the cryptocurrency market. This expansion could lead to valuable insights into which altcoins are more likely to exhibit correlation with Bitcoin and which ones are not, thereby informing investment strategies and risk management practices.

## Conclusion

The study underscores the critical importance of data quality and highlights the importance of tempering expectations regarding the capabilities of artificial intelligence (AI). Despite the widespread enthusiasm surrounding AI's potential, the findings suggest that its predictive capacity in the context of cryptocurrency markets may have limitations. This serves as a cautionary tale for both researchers and practitioners, emphasizing the need for realistic assessments of AI's capabilities and potential limitations.

We, therefore, see that artificial intelligence is not infallible, and its predictive capacity is limited to the quality and causality of the data used in the training dataset. The quality of the data and the understanding of the business have become the fundamental factors in any study, more than the algorithm used.

Future research will focus on the potential impact of altcoin legitimacy on their pricing dynamics and their predictive effect on Bitcoin. Drawing on legitimacy theory, which posits that risk diminishes with increased legitimacy (Díez-Martín et al., 2022), future studies could explore the extent to which cryptocurrency legitimacy shapes price fluctuations. This line of inquiry could provide valuable insights into whether currency acceptance influences its pricing and whether legitimacy can serve as a predictor of pricing trends.

## Statement

During the preparation of this work the authors used Chat GPT for generating ideas, developing concepts, or aiding in understanding certain topic- Also this tool has been used in translating and improving the wording. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

## CRediT authorship contribution statement

**Raúl Gómez-Martínez:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Mara Luisa Medrano-Garcia:** Writing – review & editing, Writing – original draft, Supervision.

## Declaration of competing interest

"The authors declare that there is no conflict of interest regarding the publication of this research article."

## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.stae.2024.100087.

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